Focus on Young Men in Switzerland

The Influence of Lifestyle and Environmental Factors on Semen Quality

Semen quality is a fundamental indicator of male reproductive health, with implications not only for fertility but also for overall general health. Over the past few decades, several studies have reported a significant decline in semen quality among men, raising growing concerns about male reproductive health. This review explores the influence of these factors on semen quality, with a particular focus on studies conducted on young men in Switzerland.

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Declining Semen Quality and Its Broader Implications

Since the 1980s, concerns have been raised about possible declines in semen quality, with several meta-analyses indicating downward trends in sperm concentration over recent decades, particularly in Western populations (1). While the underlying causes remain debated, environmental and lifestyle factors are thought to play a larger role than genetics (2).

Beyond fertility, semen quality is considered an important marker of overall male health (3, 4). In addition to being associated with a prolonged waiting time to pregnancy, men with poor semen quality are at a higher risk of suffering from cardiovascular and autoimmune diseases, higher morbidity rates, testicular cancer, and genital malformations (reviewed in 5). Abnormal semen parameters have also been linked to a higher risk of death, diabetes, ischemic heart disease, and substance abuse. The hypothesis of the Testicular Dysgenesis Syndrome (TDS), which describes the co-occurrence of poor semen quality, testicular cancer, and genital malformations as outcomes of a common fetal origin, further highlights the crucial role of the intrauterine environment.

Merkpunkte

- **Spermienqualität als Marker:** Sie spiegelt nicht nur die Fruchtbarkeit, sondern auch die allgemeine Gesundheit von Männern wider.
- **Rückgang:** Studien der letzten Jahre zeigen eine deutliche Abnahme der Samenkonzentration und -qualität in westlichen Ländern.
- **Risikofaktoren:** Ungünstige Einflüsse sind u. a. Nikotin- und Alkoholkonsum, mütterliches Rauchen in der Schwangerschaft, hormonaktive Chemikalien, exzessive Smartphone-Nutzung und epigenetische Veränderungen.
- **Folgen:** Schlechte Samenqualität führt zu längerer Zeit bis zur Schwangerschaft, erhöhter Infertilität und einem gesteigerten Risiko für chronische Erkrankungen.

Semen Quality in Young Swiss Men: a Nationwide Perspective

Switzerland provides a unique setting for investigating semen quality across the entire country. A nationwide cross-sectional study, conducted between 2005 and 2018, recruited 2523 young men (aged 18-22) during military conscription from all regions of Switzerland (8). This systematic sampling revealed that the median sperm concentration adjusted for the sexual abstinence period was 48 million/mL. This value is comparable to values reported in Germany, Denmark, and Sweden, but lower than those in Norway and Spain (50–59 million/mL). The study also showed that 17% of young men had sperm concentration below 15 million/mL (the 5th percentile of WHO reference values for fertile men), which might be associated with a prolonged waiting time to pregnancy when men are of reproductive age. Moreover, the incidence rates of testicular cancer in the general Swiss population significantly increased between 1980 and 2014, showing a correlation with the observed low median sperm concentration. The Swiss study on semen quality stands out for its nationwide scope, large sample size, and representative design. Unlike many earlier European studies limited to small, urban cohorts, it was the first standardized cross-sectional study to assess young men across all regions of Switzerland, enabling the evaluation of geographical variation. By recruiting over 2500 men through military conscription, the study minimized selection bias and ensured findings were broadly representative of the general male population, not just subgroups selected for fertility concerns.

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Lifestyle and Environmental Factors Influencing Semen Quality

Numerous lifestyle and environmental factors play a substantial role in male reproductive health outcomes and adversely affect semen quality, with effects already occurring during fetal life and during adulthood.

- ***Maternal smoking:***
  Prenatal exposure to cigarette smoke has consistently been associated with adverse effects on male reproductive outcomes later in life (9). Several cohort studies have reported that sons of mothers who smoked during pregnancy tend to have lower sperm concentration, reduced motility, and a higher risk of subfertility in adulthood (10). Tobacco smoke contains numerous toxicants, such as nicotine, cadmium, and polycyclic aromatic hydrocarbons, that can cross the placenta and interfere with fetal testis development, particularly during critical windows of germ cell differentiation and Sertoli cell proliferation. The Swiss study confirmed these findings, showing a higher proportion of men with impaired semen quality among those exposed in utero to maternal smoking, supporting the hypothesis that fetal exposures can have long-term consequences on male reproductive potential (8).
- ***Smoking and alcohol consumption during adulthood:***
  Cigarette smoking is a recognized risk factor for impaired male reproductive health. Tobacco smoke contains numerous reproductive toxicants that can induce oxidative stress, DNA damage, and hormonal disruption. Meta-analyses generally report reduced sperm concentration, motility, and normal morphology among smokers, with heavier and long-term exposure showing the strongest effects.
  The impact of alcohol appears more dose-dependent. Light to moderate intake is usually not associated with major changes in semen parameters, although subtle effects on hormones and DNA integrity have been described. In contrast, heavy or chronic alcohol use is consistently linked to reduced sperm concentration, lower total counts, abnormal morphology, and in severe cases spermatogenic arrest, which may improve with abstinence.
  Overall, both smoking and heavy alcohol consumption can adversely affect semen quality. In our Swiss cohort, however, we did not detect strong associations, likely due to the relatively young age of participants and the limited intensity of exposure.
- ***Mobile Phone Use:***
  The widespread use of mobile phones has raised concerns about their potential impact on semen quality. A study on 2886 young Swiss men indicated that higher mobile phone use (defined as >20 times per day) was associated with lower sperm concentration and total sperm count (TSC) (11). This higher frequency of use translated to a 30% increased risk for sperm concentration and a 21% increased risk for TSC to fall below WHO reference values. In contrast to many earlier studies, which were limited by small sample sizes and fertility clinic populations, this investigation drew on a large, representative cohort, thereby minimizing selection bias. Interestingly, this inverse association was most pronounced in the early study period (2005–2007) and gradually decreased over time (2008–2011 and 2012–2018), possibly reflecting technological advancements and reduced mobile phone output power. Keeping a mobile phone in pants pockets was not consistently associated with lower semen parameters (11).
- ***Endocrine Disrupting Chemicals (EDCs):***
  EDCs can interfere with sex steroid activity, affecting testicular development and function, potentially impacting male reproductive health from fetal life through adulthood (12). In the Swiss cross-sectional study, maternal occupational exposure to EDCs (specifically pesticides, phthalates, and heavy metals) during pregnancy was significantly associated with lower semen volume and total sperm count in their adult sons (13). A recent study in the same cohort show that prenatal exposure to phthalates or alkyl phenolic compounds was significantly associated with higher Follicle-Stimulating Hormone (FSH) levels, and pesticides were found to be linked to higher Sex-Hormone-Binding-Globulin (SHBG) levels, suggesting that maternal occupational exposure to certain EDCs during pregnancy can alter reproductive hormone levels in adult sons (14).

Paternal epigenetic inheritance

Lifestyle and environmental factors profoundly influence the sperm epigenome, leading to changes in DNA methylation, histone modifications, and small non-coding RNA (sncRNA) profiles (15). Such alterations can impair fertilization, affect embryo development, and be transmitted across generations (16). Paternal obesity, poor diet, and smoking have been linked to altered DNA methylation and sncRNA content in sperm, increasing offspring risk for metabolic and reproductive disorders. Psychological stress and exposure to EDCs such as pesticides, phthalates, and BPA can also reprogram germ cell epigenetics, with potential consequences for offspring's physical and mental health (17). Encouragingly, some effects, particularly those related to obesity, appear reversible with lifestyle changes, highlighting the importance of paternal health for both current fertility and the well-being of future generations.

Advanced Diagnostics of Semen Quality

While conventional semen analysis remains the cornerstone of male infertility diagnostics, functional assessment has gained clinical importance. Among these, sperm DNA fragmentation (SDF) is the most studied marker, with elevated levels linked to infertility, recurrent miscarriage, and implantation failure (18). Single-strand breaks are mainly associated with reduced fertilization and motility, whereas double-strand breaks impair embryonic development and increase miscarriage risk. Importantly, men with normal

semen parameters may still show high DNA fragmentation, highlighting the limits of standard analysis. The 2022 ESHRE guidelines recommend SDF testing in selected cases, such as recurrent miscarriage, though clinical use remains restricted by methodological variability and limited large-scale trials (19). Lifestyle changes, antioxidants, advanced sperm selection, and testicular sperm retrieval are potential strategies to reduce DNA damage, but their benefit is case-dependent.

From Semen Parameters to Functional Assessment and Genetic Screening

Beyond functional testing, male infertility diagnostics increasingly incorporate hormonal evaluation and standardized andrological examination, particularly in cases of abnormal semen results or suspected hypogonadism (20). Genetic testing is also gaining ground: more than 2000 genes are involved in spermatogenesis, with over 1000 pathogenic variants linked to male subfertility (21). Current guidelines recommend genetic screening (karyotyping, Y-chromosome microdeletions, CFTR testing) mainly in men with severe oligozoospermia (<5 million/ml), but expanding evidence suggests that broader use will become standard. The International Male Infertility Genomics Consortium already advocates next-generation sequencing (NGS) as a future diagnostic tool in male infertility, underscoring the shift toward a more comprehensive and personalized evaluation of male reproductive health (22).

Public Health Implications and the Need for Preventive Action

Male infertility presents significant public health implications, extending beyond the challenge of conception to serve as a biomarker for systemic illness, including an increased risk of chronic diseases such as cancer, cardiometabolic disease, and early mortality (23). The largely unexplained etiology of most male infertility cases highlights a critical knowledge gap, which can lead to missed opportunities for preventing co-morbidities and shifts the burden of medically assisted reproduction (MAR) to women. To address these issues, preventive actions must focus on increasing education and awareness among the public, governments, and clinicians about the frequency and consequences of male infertility (24). It is essential to promote better preconception and reproductive care, encompassing lifestyle modifications like smoking cessation, weight management, and reduced alcohol intake, as these can improve sperm parameters and potentially enhance offspring health. Further research into modifiable risk factors, alongside the development of targeted interventions and less invasive fertility restoration strategies, is also critical for improving male reproductive health and overall well-being across generations.

Challenges and Future Directions

Investigating the influence of environmental factors on semen quality is challenging due to the complex interplay of various exposures, genetic susceptibility, and the timing of exposure (fetal vs. adult life). The field of male fertility has also been underfunded, with advancements in MAR sometimes overshadowing research into underlying etiologies (20). Future priorities include prospective cohort studies with

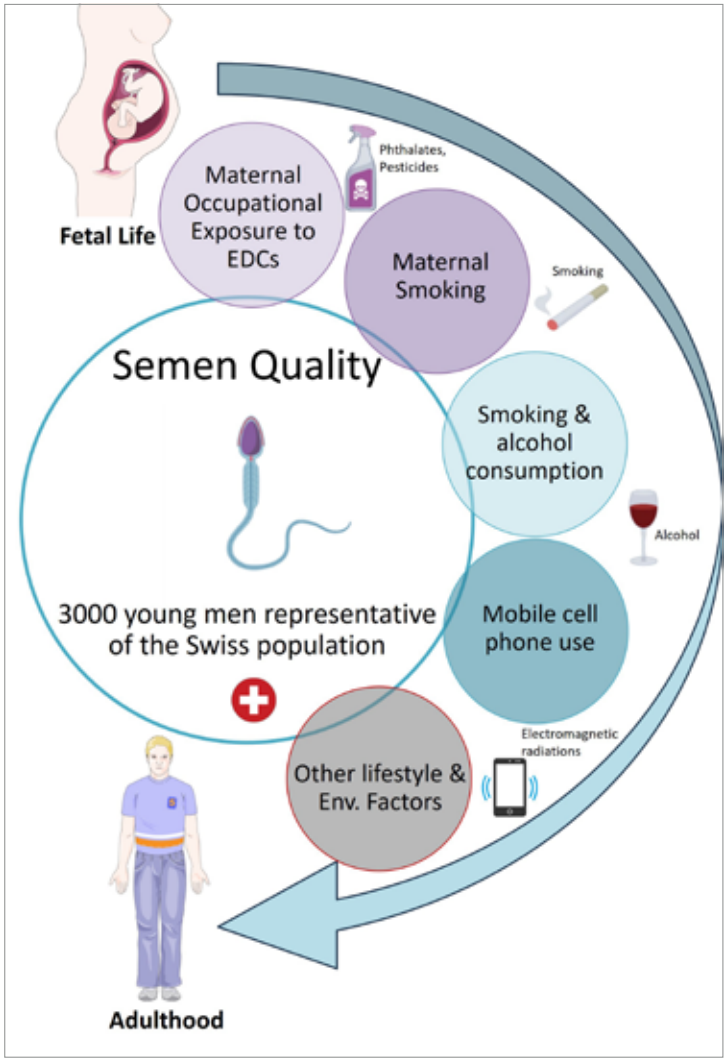

Figure: Lifestyle and environmental factors affecting semen quality from fetal life to adulthood, a focus on young Swiss men

The nationwide cross-sectional study evaluated semen quality in about 3,000 men, a cohort broadly representative of the Swiss population. Participants were recruited during mandatory military conscription between 2005 and 2018. Each man completed detailed questionnaires on demographics, education, and lifestyle, while mothers provided information on exposures around the time of conception. Association studies revealed that maternal occupational exposure to endocrine-disrupting chemicals (EDCs, e.g., phthalates, pesticides) and maternal smoking during pregnancy were linked to reduced semen quality in sons. In adulthood, mobile phone use (radiofrequency electromagnetic fields), along with other lifestyle factors such as smoking and alcohol consumption, also influences semen quality. Further prospective research is needed to clarify how semen quality is shaped across the life course, underscoring the importance of preventive strategies from early life through adulthood.
(Illustration of pregnant women and men were provided by Smart Servier).

accurate exposure data, improved assessment of environmental chemicals and lifestyle factors (e.g., mobile phone use), and mechanistic studies of sperm epigenetics. Integrating genetic, epigenetic, and environmental data will be key to understanding their combined impact on male fertility and offspring health.

In conclusion semen quality serves as a sensitive barometer of men's overall health, yet it remains vulnerable to a wide range of lifestyle and environmental influences. The ways in which these factors interact with genetic background are still poorly understood, underscoring the need for further investigation. Continued, rigorous research is urgently required to inform public health policies and to develop preventive strategies that can improve male reproductive health in Switzerland and worldwide. □

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